

Discourse Coherence and Shifting Centers in Japanese Texts

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Abstract

In languages such as Japanese, the use of *zeros*, unexpressed arguments of the verb, in utterances that shift the topic involves a risk that the meaning intended by the speaker may not be transparent to the hearer. However, this potentially undesirable conversational strategy often occurs in the course of naturally-occurring discourse. In this chapter, I report on an empirical study of 250 utterances with *zeros* in 20 Japanese newspaper articles. Each utterance is analyzed in terms of centering transitions and the form in which centers are realized by referring expressions. I also examine lexical subcategorization information, and tense and aspect in order to test the hypothesis that the speaker expects the hearer to use this information in determining global discourse structure. I explain the occurrence of *zeros* in RETAIN and ROUGH-SHIFT centering transitions, by claiming that a *zero* can only be used in these cases when the shift of centers is supported by contextual information such as lexical semantics, tense and aspect, and agreement features. I then propose an algorithm by which centering can incorporate these observations to integrate centering with global discourse structure, and thus enhance its ability for non-local pronoun resolution.

1 Introduction

Centering Theory is a computational model of discourse interpretation that examines the relationship between attentional state, the form of referring expressions, and the control of inferential processes. These goals have led to its application to the study of unexpressed arguments (henceforth *zeros*) in topic-oriented languages like Japanese, in which salient entities, recoverable by inference in a given context, are freely omitted. Centering predicts the preferred interpretation of *zeros* in situations in which the antecedent of a *zero* was realized as a center in the previous discourse.

Previous work argues that both syntactic and discourse factors associated with potential antecedents determine the preferred interpretation of *zeros* [Kuno, 1973, Kameyama, 1985,

Walker *et al.*, 1990, Iida, 1992, Walker *et al.*, 1994]. For example, a discourse entity realized as a subject is more likely to serve as the antecedent of a *zero* than a discourse entity realized as an object. Walker et al. incorporated certain discourse features into centering with their proposed rule of ZERO TOPIC ASSIGNMENT (henceforth ZTA). This proposal was motivated by the observation that a *zero* that was previously the center of attention (i.e., Cb) is easily understood as the continuing center even if it is expressed in a syntactically less salient argument position.¹ For example, a zero object in a given utterance such as 1c below, is the topic because it was the Cb in the previous utterance. As the topic, the discourse entity realized in object position is ranked higher on the Cf list than the discourse entity realized as the subject. This explains the preferred interpretation of the subsequent utterance, (1)d in this case, as will be discussed in more detail below.

- (1) a. Hanako wa siken o oete, kyoositu ni modorimasita.
Hanako TOP/SUBJ exam OBJ finish classroom to returned
Hanako returned to the classroom, having finished her exam.
- b. 0 hon o locker ni simaimasita.
SUBJ book OBJ locker in took-away
She put her books in the locker.
- c. Itumo no yooni Mitiko ga 0 deki o tazunemasita.
always like Mitiko SUBJ OBJ2 result OBJ asked
Mitiko, as usual, asked (Hanako) how she did.
- d. 0 0 zibun no tokenakkatta mondai o misemasita.
SUBJ OBJ2 self GEN solve-could-not problem OBJ showed
(Hanako) showed (Mitiko) the problems which she could not solve.

In order to further test the feasibility of ZTA and to examine strategies for keeping track of centers, this chapter examines the distribution of ZEROS in naturally occurring Japanese newspaper texts. Two initial hypotheses about the use of *zeros* are given in 2 and 3:

- (2) **Hypothesis-1**
Zeros are used to CONTINUE the center.
- (3) **Hypothesis-2**
Full NPs are used to SHIFT the center.

These hypothesis are similar to one tested for Italian in (Di Eugenio, this volume).² I report on an empirical study based on 250 utterances from a corpus of 20 Japanese newspaper articles. Each utterance is analyzed in terms of centering transitions and the form in which centers are realized by referring expressions. I also examine lexical subcategorization information, and tense and aspect in order to test the hypothesis that the speaker expects the hearer to use this information in determining global discourse structure. Figure 1 summarizes the findings on the distribution of centering transitions with respect to form of referring expression used in the utterance.

The hypothesis in (2) is confirmed by the distribution of CONTINUE transitions in Figure 1, as compared to the other transitions combined $\chi^2 = 53.932$, $p < .001$). In CONTINUE

¹The salience of the subject has also been observed in various syntactic phenomena such as extraction and binding. See Walker et al. (1994) for the discussion of salience among the arguments of the verb in Japanese.

²Di Eugenio's hypothesis says, "Typically a null subject signals a CONTINUE, and a strong pronoun a RETAIN or a SHIFT."

	CONTINUE	RETAIN	SMOOTH-SHIFT	ROUGH-SHIFT
<i>with</i> ZERO	76	3	34	23
<i>without</i> ZERO	7	39	9	35
total	83	42	42	58

Figure 1: Distribution of Centering Transitions and Zeros in Japanese newspaper texts

transitions, *zeros* are strongly preferred to NPs: among CONTINUE transitions, 76 cases appears with *zero* and only 7 cases without *zero*, while other transitions preferentially realize centers by NPs: there are 60 cases with *zeros* and 83 cases without *zeros*.

Note that Hypothesis-1 predicts as a corollary that discourse entities ranked higher in the Cf ranking would tend to be realized by *zeros*. The preference of *zeros* in CONTINUE transitions proves this tendency and provides additional support for Walker et al.’s rule of ZERO TOPIC ASSIGNMENT.

However, the second hypothesis in 3 is disconfirmed: while the frequency of full NPs is greater (83) than zeros (60), full NPs are **not** always used to shift the center, and zeros frequently are. The distribution of centering transitions in figure 1 shows that a shift of attentional state is abundant in naturally occurring discourse, as seen by the frequency of RETAIN and ROUGH-SHIFT, which the centering algorithm prefers the least [Brennan *et al.*, 1987]. In the Japanese data examined here, these transition states are identified when a ZERO cannot take the current center of attention, the Cb, as its antecedent.

Thus, what needs to be explained is the occurrence of *zeros* in these transitions in which the Cb changes, where it may be difficult for the hearer to determine which discourse entity is realized by the *zero*. How is discourse coherence preserved when two adjacent utterances are not locally coherent? In the transition state of RETAIN, the rule of ZTA makes it is possible to avoid shifting the Cb, but in a ROUGH-SHIFT transition, there is no link to the prior utterance, and the Cb must shift.³

The main focus of this chapter is to study the relation of local and global structure in discourse, by exploring the strategies that a speaker uses to reduce the hearer’s inference load and make the flow of discourse coherent when the antecedent of a *zero* is not realized in the immediately preceding utterance. In section 2, I discuss in more detail how centering works in Japanese and the rule of ZERO TOPIC ASSIGNMENT [Walker *et al.*, 1994]. Then in section 3, I show how cues such as lexical semantics and tense and aspect can be used to interpret zeros in utterances that realize ROUGH SHIFT transitions. On the basis of this analysis, section 4 sketches an algorithm for integrating centering with global focus, and finally section 5 summarizes the contributions of the chapter.

³What I call a ROUGH SHIFT in this chapter is elsewhere called a NO CB transition. That is, there is no Cb as no entity from the Cf(U_{n-1}) is realized in the current utterance.

2 Zero Topic Assignment and Disambiguation

In this section, I briefly describe the ZTA rule proposed by Walker et al. and show that discourse coherence indeed tends to be maintained with the same discourse topic across utterances. In Walker et al., the centering algorithm specifies two structures for centers, namely Cb (BACKWARD-LOOKING CENTER) and Cf (FORWARD-LOOKING CENTERS), and a set of rules and constraints (See Walker, Joshi and Prince, this volume). FORWARD-LOOKING CENTERS are a set of semantic discourse entities associated with each utterance. The Cf Ranking for Japanese according to discourse salience is given in (4).

- (4) TOPIC > EMPATHY > SUBJECT > OBJECT2 > OBJECT > OTHERS

The highest ranked member of the Cf list is called the Cp (PREFERRED CENTER). The Cp represents a prediction about the Cb of the following utterance. The BACKWARD-LOOKING CENTER is the discourse entity that the utterance most centrally concerns. Discourse coherence is computed with this distinction between looking back to the previous discourse with the Cb and projecting preferences for interpretation in subsequence discourse with the Cp. In other words, the combination of the Cb and the Cp reflects the coherence of the discourse. The shift of centers is realized when a new entity is introduced as the Cp.

These interactions of the Cb and Cp are stated as a set of constraints and rules (Walker, Joshi and Prince, this volume). What the constraints and rules amount to is the idea that discourse segments that continue centering the same entity are more coherent and easier to process than those that repeatedly shift from one center to another. The theory measures coherence by the hearer's inference load when interpreting a discourse sequence [Grosz *et al.*, 1986, Grosz *et al.*, 1995].

ZERO TOPIC ASSIGNMENT is a discourse rule which allows a *zero* to be interpreted as a ZERO TOPIC. ZTA is applied when there is no CONTINUE transition of the previous center.

(5) **Zero Topic Assignment**

When a zero in U_{i+1} represents an entity that was the Cb(U_i), and when no other CONTINUE transition is available, that zero may be interpreted as the ZERO TOPIC of U_{i+1} .

The rule allows a *zero* that has been the Cb in U_{i-1} to continue as the Cp in U_i , even if it appears in a less salient syntactic position. It explains why the discourse entity Hanako, which is realized as the OBJECT2 in (6)c is interpreted as the SUBJECT in (6)d. Consider again example (1) repeated here as (6), with the centering data structures:

- (6) a. Hanako wa siken o oete, kyoositu ni modorimasita.

Hanako TOP/SUBJ exam OBJ finish classroom to returned
Hanako returned to the classroom, having finished her exam.

Cb:	HANAKO
Cf:	[HANAKO, EXAM]

- b. 0 hon o locker ni simaimasita.

SUBJ book OBJ locker in took-away
She put her books in the locker.

Cb:	HANAKO
Cf:	[HANAKO, BOOK, LOCKER] CONTINUE

- c. Itumo no yooni Mitiko ga 0 deki o tazunemasita.
 always like Mitiko SUBJ OBJ2 result OBJ asked
Mitiko, as usual, asked (Hanako) how she did.

Cb:	HANAKO
Cf1:	[HANAKO, MITIKO, RESULT] ZTA CONTINUE TOP, SUBJ, OBJ
Cf2:	[MITIKO, HANAKO, RESULT] RETAIN SUBJ, OBJ2, OBJ

- d. 0 0 zibun no tokenakkatta mondai o misemasita.
 SUBJ OBJ2 self GEN solve-could-not problem OBJ showed
(Hanako) showed (Mitiko) the problems which she could not solve.
(Mitiko) showed (Hanako) the problems which she could not solve.

Cb1:	HANAKO
Cf1:	[HANAKO, MITIKO, PROBLEM] CONTINUE from Cf1(c) SUBJ, OBJ2, OBJ
Cb2:	MITIKO
Cf2:	[MITIKO, HANAKO, PROBLEM] SMOOTH-SHIFT from Cf2(c) SUBJ, OBJ2, OBJ

The discourse situation in (6) is a case where the hearer may maintain multiple hypotheses about where the speaker's attention is directed. There are two assumptions available, the assumption that ZTA applies and the *zero* is interpreted as the topic, versus the assumption that subjects are more highly ranked than objects on the Cf. Cf2 of (6)c is the only Cf possible without ZTA, and represents a RETAIN rather than a CONTINUE. By the formulation of the ZTA rule above, ZTA is triggered here since no CONTINUE transition is otherwise available. Cf1 represents a CONTINUE reading due to the ZTA option; HANAKO can be the Cp even when MITIKO is realized as the subject. This could lead to a potential ambiguity in (6)d, because it is possible for a hearer to simultaneously entertain both of the Cfs in (6)c. However, the CONTINUE interpretation which results from the ZTA CONTINUE transition state is strongly preferred. Walker et al (1994) reported that 28 out of 34 speakers preferred the CONTINUE interpretation in (6d); ($Z = 4.95, p < .001$). The less preferred SMOOTH-SHIFT interpretation would come from the algorithm's application to Cf2 of (6)c.

Walker et al. make a distinction between the notions of GRAMMATICAL TOPIC and ZERO TOPIC. The grammatical topic is the *wa*-marked entity, which is by default predicted to be the most salient entity. The interaction between the grammatical topic and the zero topic is observed in (7). Discourse segment (7) uses the *wa*-marked NP instead of the GA-marked NP in the ZTA environment of (7)c. Compare the interpretation of (7)d with (6)d.

- (7) a. Hanako wa siken o oete, kyoositu ni modorimasita.
 Hanako TOP/SUBJ exam OBJ finish classroom to returned
Hanako returned to the classroom, having finished her exam.

Cb:	HANAKO
Cf:	[HANAKO, EXAM]

- b. 0 hon o locker ni simaimasita.
 SUBJ book OBJ locker in took-away
(Hanako) put (her) books in the locker.

Cb:	HANAKO
Cf:	[HANAKO, BOOK] CONTINUE

- c. Itumo no yooni Mitiko wa 0 deki o tazunemasita.
 always like Mitiko TOP/SUBJ OBJ2 result OBJ asked
Mitiko, as usual, asked (Hanako) how she did.

Cb:	HANAKO
Cf1:	[HANAKO, MITIKO, RESULT] ZTA CONTINUE ZERO-TOP, TOP/SUBJ, OBJ
Cf2:	[MITIKO, HANAKO, RESULT] RETAIN TOP/SUBJ, OBJ2, OBJ

- d. 0 0 zibun no tokenakkatta mondai o misemasita.
 SUBJ OBJ2 self GEN solve-could-not problem OBJ showed
(Hanako) showed (Mitiko) the problems which she could not solve.
(Mitiko) showed (Hanako) the problems which she could not solve.

Cb1:	HANAKO
Cf1:	[HANAKO, MITIKO, PROBLEM] CONTINUE from Cf1(c) SUBJ, OBJ2, OBJ
Cb2:	MITIKO
Cf2:	[MITIKO, HANAKO, PROBLEM] SMOOTH-SHIFT from Cf2(c) SUBJ, OBJ2, OBJ

The *wa* marking has the predicted effect. Using the grammatical topic marker *wa* in (7)c dampens ZTA and thus affects the interpretation of (7)d, which is now completely ambiguous. The results of experiments reported in [Walker *et al.*, 1994] show that 10 subjects who prefer an interpretation that depends on ZTA in (6) can no longer get the interpretation in (7). In (7)d, only 18 out of 34 subjects prefer the ZTA CONTINUE interpretation. Because the discourse entity realized as the grammatical topic and indicated by the *wa*-marked NP is the Cp by default, it is harder to interpret the *zero* as the topic. The situation can be characterized as a case of competing defaults; some hearers apply the default that the *wa*-marked entity is usually the Cp, and others apply the default that CONTINUE interpretations are preferred and that *zeros* realize discourse entities that are ranked highly on the Cf.

When an ambiguity arises from the use of the WA-marked NP in the ZTA environments as illustrated in the above example, it is often resolved with additional information provided in the subsequent discourse. Consider (8).⁴

- (8) a. S International wa sirikon-varee ni kenkyuusyo o kaisetusuru.
 S International TOP/SUBJ silicon valley in laboratory OBJ establish
(S International) establishes a laboratory in Silicon Valley.
 b. 0 sutaffu tosite doobunya no keni hutari o sukautosita.
 SUBJ staff as this-field GEN authority 2-people OBJ recruited
(S International) has recruited two authorities in the field as a staff.

Cb:	S INTERNATIONAL
Cf:	[S INTERNATIONAL, TWO AUTHORITIES]

- c. Kono kenkyuusyo wa 0 saniibeeru ni kaisetusi,
 this laboratory TOP/OBJ SUBJ Sunnyvale in open
(S International) will open this laboratory in Sunnyvale,

⁴There is no decisive proposal how complex sentences should be divided and arranged. In this study, I simply divide a complex sentence into simplex sentences and arranged them in serial order. The complex sentences which appeared in the data consist of coordinations and compounds with temporal adjunct clauses. A temporal subordinate clause is followed by the main clause in Japanese, so simple serial ordering normally preserves their chronological order.

Cb:	S INTERNATIONAL
Cf1:	[S INTERNATIONAL, LABORATORY] ZTA CONTINUE ZERO-TOP, TOP/OBJ
Cf2:	[LABORATORY, S INTERNATIONAL] RETAIN TOP/OBJ, SUBJ

- d. 0 0 “Oputo-huirumu-kenkyuusyo” to nazukeru.
 SUBJ OBJ Opt-film-laboratory as name
(S International) names (the laboratory) Opt-film Laboratory.

Cb:	S INTERNATIONAL
Cf:	[S INTERNATIONAL, LABORATORY]

Recall that the ZTA effects are dampened when the grammatical topic marker *wa* is used. The third sentence yields the situation where the zero topic must compete with the grammatical topic, and the preference for one over the other is hard to determine. The ambiguity is resolved after processing the fourth sentence, however, when semantic information about the naming relation is provided. In other words, the inference that a newly created thing is normally given a name, allows the hearer to hypothesize that *the laboratory* naturally fills the *named* slot of the *naming* relation.

In sum, these observations support the predictions made by centering that the preferred interpretation of utterances that contain *zeros* is one in which discourse coherence is maintained. Furthermore, ZTA allows the hearer to interpret the current utterance as being highly coherent with the previous utterance. I have also suggested that in cases where an ambiguity arises because of the use of ZTA, the speaker will provide additional cues to guide the hearer’s interpretive process.

3 The Shift of Attentional Focus

Now let us consider the prediction that discourse coherence is maintained even when zeros are used to shift the center. This is the context in which the Cb in utterance U_i is not realized as the Cp (i.e. the most salient entity in U_i). A new entity is introduced as the Cp, and the shift of the speaker’s attentional focus onto this new entity is indicated. Below, I examine the interpretation of *zeros* in RETAIN (discourses (9) and (10)) and ROUGH-SHIFT (Discourses (11) and (12)) transitions. After discussing these examples, I propose some hypotheses about how zeros are interpreted in these environments.

In (9c) a new center, *T co.* is introduced into the discourse and realized as a topic, while the old center, *the student* is realized as an object. Thus the center realized by *the student* is ranked lower on the Cf than the center realized by *T co.*, but *the student* is still the Cb, so the centering transition is a RETAIN.

- (9) a. Gakusei wa hurii-daiaru-kaado de G-sya e denwasureba,
 students TOP/SUBJ free-dial card with G. Company to phone
When students call G. Company with the phone card,
 b. 0 syuusyoku-zyoohoo o muryoo-de erareru.
 SUBJ employment-information OBJ free get-can
(The student) can get employment information free.
 c. T-sya wa rezyaa-zyoohoo o 0 fakusimiri de teikyusiteori,
 T Co. TOP/SUBJ leisure info. OBJ OBJ2 fax by provide
T Co. provides leisure information (to student) by fax,

In (10c) a new center, *the price* is introduced into the discourse and realized as a topic, and the center for *the bank* is realized as a subject. Thus the center for *the bank* is ranked lower on the Cf than the center for *the price.*, but *the bank* is still the Cb, so the centering transition is a RETAIN.

- (10) a. Saga Ginkoo wa gasorin-sutando de "banku POS" saabisu o hazimeru.
 Saga Bank TOP/SUBJ gas station at "Bank POS" service OBJ will start
Saga Bank will start "Bank POS" service at gas stations.
- b. 0 kaimono-kayku ni kyassyu-kaado wo tukatte-morai,
 SUBJ shoppers OBJ2 cash card OBJ use-ask
(the bank) asks shoppers to use a credit card,
- c. daikin wa 0 sokuza-ni kokyaku no kooza kara hikiotosu.
 price TOP/OBJ SUBJ immediately customer POSS account from draw
(the bank) takes the charge immediately from a customer's account.

In (11c), the only center that provides a link to the prior discourse is the center for *the customer*, so that center is the Cb. However *the customer* is ranked lower on the Cf than the center for *T. Insurance Co.*, yielding a ROUGH SHIFT centering transition.

- (11) a. S. ginkoo wa kinyuu-hosyoo-seido no toriatukai mo hazimeru.
 S. Bank. TOP/SUBJ money-insurance-system GEN handling OBJ begin
S. Bank will start to handle a money insurance system as well.
- b. Kokyaku ga ittei ryookin o haraeba,
 customer SUBJ certain fee OBJ pay
A customer pays a certain amount of fee,
- c. T. Insurance Co. ga sono kinyuu-torihiki o 0 hosyoosuru.
 T. Insurance Co. SUBJ that money-transaction OBJ OBJ2 insure
T Insurance Co. insures the money transaction (to the customer).

In (12a), the phrase *T. Electron* introduces a center that is established as the Cb in (12b). Other discourse entities become the Cb in utterances (12d)) to (12)f, but in (12g) the center corresponding to *T. Electron* is realized by a *zero*. None of the centers in (12)f serve as an antecedent for this zero, so this is a ROUGH SHIFT transition.

- (12) a. T. Electron wa Yamanasi-ken Nirasaki-si ni daikibona
 T. Electron TOP/SUBJ Yamanasi, Nirasaku-city in big
 koozyoo o kaisetusuru.
 factory OBJ will built.
T.E lectron will open the big factory in Nirasaki City, Yamanasi
- b. (a few sentences about T. Electron)
- c. Sinkoozyoo de seisansuru sooti wa TE5000 o
 new factory in produce-is devices TOP/SUBJ TE5000 OBJ
 seinoo-appu-sita RIE-ettingu-sooti.
 power-up-did RIE-etching-devices
*The devices that produced in the new factory are RIE etching devices,
 more powerful than TE5000.*
- d. 0 16MDRAM no sesan ni taioodekiru.
 SUBJ 16MDRAM GEN production OBJ2 cope-with
(RIE devices) can cope with the production of 16 MDRAM.
- e. DRAM no syuusekido ga takamaruniture,
 DRAM GEN integrality SUBJ increase
As the integrality of DRAM increases,

- f. ettyaa no zyuyoo ga hueru tame,
 etching-devices GEN demand SUBJ increase since
The demand of etching devices increases, and hence,
- g. 0 sinkoozyoo no seisan ni humikitta.
 SUBJ new facility GEN production OBJ2 decided
(T. Electron) decided to begin the production in the new facility.

Note that the interpretation of *zeros* is not particularly problematic in the case of RETAIN; although the Cb is shifting the antecedent for the *zero* is a center from the previous utterance. Furthermore, in some cases, the RETAIN transitions may have a ZTA CONTINUE option. However in the ROUGH-SHIFT transition, no local antecedent of a *zero* is available and a center shift is forced. In this second case, the *zero*'s antecedent is not in the immediately preceding utterance, but must be realized in prior utterances. These cases have been called RETURN POPS or FOCUS POPS in the literature [Reichman, 1985, Polanyi and Scha, 1984, Grosz and Sidner, 1986]. See also (Walker, this volume).

	LEXICAL SEMANTICS	TENSE & ASPECT	AGREEMENT
ROUGH-SHIFT with <i>zeros</i>	20	6	2

Figure 2: **Disambiguation Features for Rough-Shift**

If discourse coherence is to be maintained, it seems clear that there must be other cues that are used to preserve coherence and resolve *zeros* appropriately. This prediction has turned out to be correct. To test the hypothesis that shifting centers are associated with contextual factors that facilitate transitions, such as lexical semantics, agreement information and tense and aspect, all the rough shifts in the corpus (23 of them) were coded for these features. The results are given in figure 2.⁵ Below I illustrate the role of these factors in interpreting *zeros* when the center shifts with representative examples from the corpus.

3.1 Interaction with lexical semantics

Let us take a look at the discourse in (12). The appropriate interpretation of the *zero* in the last sentence is constrained by the semantic restriction assigned to the arguments of verb ‘decide’. No entity in (12)f can be a potential antecedent, and the *zero* must be resolved to a discourse entity expressed in the previous utterances of the text. In this case, it goes back to the utterance where *T. Electron* is available.⁶

- (13) **T. Electron** *will open the biggest factory in Nirasaki City, Yamanashi.* (T. Electron) will build (the factory) in the company property adjacent to its General Laboratory. (T. Electron) will provide a big-scale clean room, and produce etching devices which can deal with 16M bit dynamic RAM. The total investment amounts to 5 billion yen and the construction starts this fall. It is expected that (the factory) will start operation in a year later. *The devices produced in the new factory*

⁵The total number of the table exceeds the total number of 23 occurrences of the ROUGH-SHIFT transition with zeros. This is due to the fact that there are some cases where two features (i.e. lexical semantics and tense) are employed at the same time.

⁶The part indicated by italics is the segment given in (12).

are RIE devices, more powerful than TE5000. (RIE devices) can cope with the production of 16MDRAM. As the integrality of DRAM increases, the demand of etching devices increases, and hence, (T. Electron) decided to begin the production in the new facility.

If we assume that the antecedent of a *zero* is any of the centers introduced in the previous discourse, the interpretation of the last sentence would be ambiguous; there are multiple potential candidates even if lexical information is brought to bear. Note that *Nirasaki City* and *General Laboratory* are semantically legitimate antecedents of the missing subject of the *deciding*-situation described by the last sentence. The uncontroversial interpretation with *T. Electron* as the antecedent suggests that a discourse entity that has not been previously realized as the Cb **cannot** be interpreted as the cospecifier of a *zero*.

Discourse coherence can be maintained by an inference process based on the lexical semantics, but the preferred interpretation is not always computed by a inference process purely driven by the underlying semantics. Instead, discourse information such as attentional focus and salience provides constraints on the application of information from lexical semantics. This interaction is key for enhancing centering by incorporating disambiguation information from other sources.

This claim is further supported by the observation in (14). If we assume that the antecedent of a *zero* can be any of the entities that were previously realized in a discourse, nothing stops the *zero* in the third utterance from taking *doosya* ('the company') in the first utterance as its antecedent since this would yield a semantically plausible ROUGH-SHIFT interpretation. However, this interpretation is never preferred over the interpretation obtained by a more highly ranked centering transition. That is, no interpretation based on lexical semantics is preferred to an interpretation that is ranked higher in terms of centering transitions. The preferred interpretation according to the centering rules cannot be overridden unless this interpretation is semantically anomalous.

- (14) a. doosya wa 15-dai no hanbai o mikondeiru.
 company TOP/SUBJ 15-piece GEN sales OBJ anticipate
The company anticipates the sales of 15 machines.

Cb:	COMPANY
Cf:	[COMPANY, SALES]

- b. CVD-sooti wa CERAUS.
 CVD-device TOP/SUBJ CERAUS
The CVD device is (called) CERAUS.

Cb:	COMPANY
Cf:	[CVD-DEVICE, CERAUS] RETAIN

- c. 0 maruti-tyenbaa-hoosiki o saiyo.
 SUBJ multi-chamber system OBJ adopt
(CVD-device) adopts a multi-chamber system.

Cb1:	CVD-DEVICE
Cf1:	[CVD-DEVICE, SYSTEM] SMOOTH-SHIFT SUBJ, OBJ
Cb2:	CVD-DEVICE
Cf2:	[COMPANY, SYSTEM] ROUGH-SHIFT SUBJ, OBJ

- d. 0 tahaisen-maku ni taioo-dekiru.
 SUBJ multi-wired film OBJ2 deal-can
(CVD-device) can deal with multi-wired films.

Cb1:	CVD-DEVICE
Cf1:	[CVD-DEVICE, FILMS] CONTINUE SUBJ, OBJ2
Cb2:	COMPANY
Cf2:	[COMPANY, FILMS] SMOOTH-SHIFT SUBJ, OBJ2

The lexical semantics of the verb *saiyoo* (‘adopt’) in (14)c would not block *the company* in (14a) being realized as their subject. For instance, both ‘*The CVD-device adopts a multi-chamber system*’ and ‘*the company adopts a multi-chamber system*’ are reasonable readings of (14)c. However, the Cf2 reading, which is obtained on the basis of lexical semantics and yields the ROUGH-SHIFT transition, is not preferred to the Cf1 SMOOTH-SHIFT reading. The preference assigned to (14c) based on centering transitions is seen in (14)d.

The verb *taioo* in (14d) means ‘answer’ or ‘response’ when the human being or the organization is the subject, and it normally takes an abstract noun such as ‘demand’, ‘a political crisis’ as its object. The verb also takes the non-agentive entity as the subject and means its applicability to some other object expressed in the non-subject position. The missing subject of the sentence in (14)d, which has a concrete object in the object2 position, therefore naturally refers to *the CVD device* rather than *the company*, meaning that the CVD device is applicable to handle multi-wired films. The preferred interpretation of (14)d thus supports the preference computed in utterance (14)c based on the centering transitions; the interpretation, which preserves discourse coherence between discourse segments, is the one most preferred.

Thus, lexical semantics can be used to resolve the interpretation of *zeros*, as long as its interaction with discourse information about attentional state is taken into consideration.

3.2 Interaction with tense and aspect

It is not always the case that lexical semantics provides a cue. Observe the following examples.

- (15) a. T. Electron wa hiitaa-koozyoo no kensetu ni tyakusyusita.
T Electron TOP/SUBJ heater factory GEN construction OBJ began(PAST)
T. Electron began the construction of its heater factory.
- b. koremade 0 kyoodaigaisya kara kyookyuu o uketeita ga,
by now SUBJ brother-company from supply OBJ recieved but
By now (T. Electron) has been receiving the supply from its brother company,
- c. 0 zisya-seisan ni kirikaeteiku.
SUBJ self-production OBJ2 introduce
(T. Electron) will introduce self-production.
- d. Hiitaa-koozyoo wa 0 itagane-koozyoo ni rinsetusite kensetusuru.
Heater factory TOP/OBJ SUBJ steel factory to adacent construct.
(T.Electron) is constructing the heater factory next to the steel factory.
- e. 0 hiraya-date de, yukamenseki 658 heihoo-meetoru.
SUBJ one-story is floor space 658 square meter
(The heater factory) is one-story building with the floor space of 685 square meter.
- f. 0 CVD-sooti-yoo hiitaa o seisansuru.
SUBJ CVD-device-for heater OBJ produce
(The heater factory) will produce heaters for CVD-devices.

- g. Toosigaku wa 2-oku 8-sen man yen da.
investment-money TOP/SUBJ 280 million yen is
The investment money amounts to 280 million yen.

Cb:	HEATER FACTORY
Cf:	[INVESTMENT, 280 MILLION YEN] RETAIN
	SUBJ, COMP

- h. 0 san'nin no gizyutusya o Sagami ni gizyutusuutoku tame hakensita.
SUBJ three GEN technician OBJ Sagami to technical training for sent
(T. Electron) sent three technicians to Sagami for technical training.

Cb1:	INVESTMENT MONEY
Cf1:	[HEATER FACTORY, TECHNICIAN] ROUGH-SHIFT
	SUBJ, OBJ
Cb2:	INVESTMENT MONEY
Cf2:	[T. ELECTRON, TECHNICIAN] ROUGH-SHIFT
	SUBJ, OBJ

No entity in (15)g is suitable as an antecedent of the *zero* in (15)h – *the investment money* is never interpreted as the *sender* in (15).⁷ That is, the ROUGH-SHIFT transition is forced to make sense out of (15)h and the *zero* looks for its potential antecedent in the previous utterances. There are two entities whose semantics is compatible with what the verb of the sentence requires as its argument. That is, it is both plausible to say that ‘*The heater factory (as an organization, though the construction of its building has not been completed) sent technicians*’ as well as ‘*T. Electron sent technicians*’. However, the second reading is more preferred. I assume that the shift is supported by the use of the past tense:⁸ the attentional focus in (15)h returns to an event which has been completed at the time of the utterance. Note that *T Electron* has been mentioned as an entity which conducted some past action at the beginning of the text.

The example illustrates how inference based on temporal/aspectual information can be used to resolve ambiguity when no local constraints are available. They are used to control

⁷Here *heater factory* and *T. Electron*, realized in the previous discourse segments, are potential antecedents of the *zero* because they both meet the constraints on the antecedency of zeros and the semantics of the verb. However, the following alternative analysis would be possible. The introduction of a new entity, *tossigaku* (‘investment money’) in (15)g may indicate that this entity is associated with an entity that has been already introduced in the discourse. That is, we can assume that there is functional dependency relation between *heater factory* and *investment money*; *investment money* is the money for establishing the heater factory. In other words, the heater factory might be implicitly realized in (15)h though it is not overtly expressed. More research should be done to formalize when such an implicit relation is realized. A statistical measure of cooccurrence of NPs may be useful to identify potential attributes associated with an entity. For instance, a company may have attributes NAME, LOCATION, OWNED-BY, PRODUCT, NET-WORTH, NATIONALITY and THE NUMBER OF EMPLOYEES and so on.

⁸Tense in Japanese is realized as the morpheme attached to the verb stem. In general, for the [–stative] verbs, the simple present (or non-past) tense is marked with *-u*, while the simple past (or perfect) tense with *-ta*. The present tense form of [–stative] verbs usually refers to future time unless they represent habitual or generic actions, in which case they refer to present time (Kuno 1973). The past form represents an action that has been completed or executed at reference time.

the flow of information, indicating the shift of the reference point in describing events. In other words, temporal/aspectual coherence participates in an inference system to maintain non-local coherence and it provides a cue to identify discourse structure segments and their non-local hierarchical relations in discourse.

3.3 Interaction with agreement

The third strategy to maintain discourse coherence is one that uses different types of agreement information in order to elicit adequate inference and eliminate an undesired potential interpretation. Consider example (16).

- (16) a. *S. Metal wa zisedaigata ettingu-sooti o kaihatu,*
S. Metal TOP/SUBJ next-generation-type etching-device OBJ develop
S. Metal has developed next-generation type etching devices,
 b. *0 kotosi kara honkakuteki-na maaketingu o hazimeteiru.*
SUBJ this year from full-scale marketing OBJ begin
(S. Metal) has started full-scale marketing this year.
 c. (a few sentences about *the etching device*)
 d. *CVD-sooti wa kore ni tuzuku mono de,*
CVD-device TOP/SUB this OBJ2 follow thing be
CVD devices are the thing that will follow this (i.e. etching devices).
 e. *habahiroi zyuyoo ga kitaisareteiru.*
wide demand SUBJ is-expected
Wide range of demand is expected.
 f. *0 tomoni ECR o riyositeori,*
SUBJ both ECR OBJ use
(CVD devices and etching devices) both use ECR,

The adverb *tomoni* ('both') in (16)f indicates that the unexpressed subject in the utterance refers to a set of two entities. Considering the previous discourse, we see that the entities which are of the same type and can form a set in this discourse segments are *etching devices* and *CVD devices*. Without this quantifier-like adverb, the *zero* could refer to *S. Metal*, which is an legitimate antecedent of the *zero* by itself.

Although the language does not mark number distinction (i.e. singular vs. plural) on nouns, classifiers are used when the number or the quantity does matter; *two cups of tea*, *3 individuals of professors*, *5 things of apples* and so on. Expressions which are sensitive to number as in (16) thus can be used to make an adequate grouping among the entities in a discourse and prune an undesired interpretation which is otherwise predicted or never eliminated by basic discourse coherence principles.

3.4 Summary

In conclusion, a shift of centers occurs only when such an intended interpretation is well supported by other contextual information, so that the speaker's intention is rarely misinterpreted. If the speaker is concerned that her utterance might be misinterpreted as a consequence of shifting the topic, she always has an alternative to express the intended new topic overtly as I originally hypothesized in (3) above. However, constraints that arise from lexical semantics and the event structure appear to be readily available cues

that the hearer can use to interpret zeros with nonlocal antecedents. In the following section, I will discuss how these observations can be incorporated into centering, and go some way towards integrating centering with a model of global discourse structure (cf. [Hobbs, 1985, Polanyi and Scha, 1984, Reichman, 1985, Grosz and Sidner, 1986]).

4 Integrating Centering and Global Coherence

Although our initial hypothesis was that zeros would not be used to shift centers, we saw above that this often happens in naturally occurring discourse. The relevant numbers are repeated with the definition of the various centering transitions in figure 3.⁹

	$Cb(U_i) = Cb(U_{i-1})$	$Cb(U_i) \neq Cb(U_{i-1})$
$Cb(U_i) = Cp(U_i)$	CONTINUE 76	SMOOTH-SHIFT 34
$Cb(U_i) \neq Cp(U_i)$	RETAIN 3	ROUGH-SHIFT 23

Figure 3: **Distribution of Centering Transitions with Zeros**

In the current algorithms of Centering Theory [Brennan *et al.*, 1987, Walker *et al.*, 1994], interpretations are determined by the Cb and Cf in U_{i-1} and U_i (i.e. local discourse entities). However, the observations above suggest that the theory must support an algorithm for accessing non-local antecedents when a ROUGH-SHIFT transition occurs and a shift to a non-local center is detected (cf. [Sidner, 1983]).

In order to capture global coherence, another center data structure must be added to keep track of the Cbs introduced in the previous utterances. My data shows that *zeros* in ROUGH-SHIFTS realize discourse entities that were previously realized as the $Cb(U_{i-n})$: there are **no** cases where a *zero* realizes a discourse entity that was previously a non-Cb. Thus I propose that what is needed is a Cb retrieval mechanism of some type to model the cases where a zero is resolved to a discourse entity that was an earlier center.

This Cb retrieval mechanism could be based on the stack mechanism of [Sidner, 1983, Grosz and Sidner, 1986], or the cache mechanism proposed in [Walker, 1996] and discussed in (Walker, this volume). Since I have no evidence that anything more powerful than a LIST is required, the proposed algorithm is to search a linearly ordered LIST of former Cbs, ordered by recency. In all the cases in my data, it is sufficient to search back through a list of former Cbs ordered by recency and choose as the antecedent of the zero the first such Cb that is semantically compatible with the requirements of the zero. This mechanism for computing global coherence must interact with the centering algorithm for local coherence in such a way that the former is activated when the latter fails. The condition may be stated as follows.

- (17) If $Cb(U_i) \neq Cp(U_i)$, then take $Cb(U_m)$ which is an element of M (i.e. $Cb(U_m) \in M$) where M is a list of $Cb(U_{1...(i-1)})$ which satisfies the inference process.

When local coherence is not observed and the shift of the center is forced, the list of the Cbs of the previous discourse, M, is searched, and each proposed Cb is checked against an

⁹Note that Figure 3 table shows the frequency of each transition when an utterance contains at least one *zero*.

inference process based on lexical semantics and tense and aspect information, to determine its adequacy. The algorithms to refer to the global discourse may be sketched as in (18).

- (18) When a Cb shift is detected (i.e. $Cp(U_i) \neq Cb(U_i)$):
1. **Local Coherence Check:**
 - if* RETAIN and no ZTA-CONTINUE is available, go to Global Coherence Check
 - if* ROUGH-SHIFT, go to Global Coherence Check
 - else* return to Centering algorithm
 2. **Global Coherence Check:**
 - Take a $Cb(U_m)$ on the Cb list, and (e.g. $Cp(U_m) \in M$)
 - Employ inference systems
 3. **Decision:**
 - if* the interpretation $Cp(U_i) = Cb(U_m)$ is acceptable, return to Centering algorithm
 - else* return to Global Coherence Check and try the next Cb on the Cb list

5 Discussion

In this chapter, I discuss issues that centering theory needs to address in order to model discourse coherence in a larger context. I argue that the use of *zeros* to realize previous Cbs in RETAIN and ROUGH-SHIFT centering transition states indicates that coherence information provides constraints on inferential processes. Future work must integrate these observations with other studies on shifting centers. The data examined here show that lexical semantics as well as temporal/aspectual information are used to create links between non-local utterances, and that Centering theory can be extended to compute non-local discourse coherence as long as it incorporates a richer semantic representation of utterances. I propose that the combination of the centering algorithm with a global Cb list captures some aspects of global coherence, without introducing a completely different module. This kind of mechanism suggests that it might be possible to use Centering as a part of an algorithm for inferring discourse structure.

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